EXPLORING PRESERVICE TEACHERS' EMBODIED NOTICING OF STUDENTS' FRACTION DIVISION

Karl W. Kosko
Kent State University
kkosko1@kent.edu

Temitope Egbedeyi
Kent State University
tegbedey@kent.edu

Enrico Gandolfi
Kent State University
egandol1@kent.edu

There is emerging evidence that professional noticing is embodied. Yet, there is still a need to better under embodied noticing at a fundamental level, especially from the preservice teachers. This study used traditional and holographic video, along with eye-tracking technology, to examine how preservice teachers' physical act of looking interacts with their professional noticing. The findings revealed that many participants focused on less sophisticated forms of mathematical noticing of students' reasoning. Additionally, results from eye-tracking data suggest that the more participants described students' conceptual reasoning, the more likely they were to focus on how recorded students used their hands to engage in the mathematics.

Keywords: Teacher Noticing; Technology; Preservice Teacher Education.

Professional noticing involves attending to key pedagogical events and interpreting those events based on one's knowledge and experience(s) (Jacobs et al., 2010; van Es & Sherin, 2021). At the same time, noticing is an "embodied way of accessing, exploring, and engaging with the world of classroom events" (Scheiner, 2021, p. 88). Thus, what teachers perceive and attend to both informs and is informed by the environment they notice within, and their physiological resources (eyes, body positioning, etc.). The notion of noticing as tied to the senses is not new, with analyses and conceptual descriptions focusing both on what teachers see and hear in a classroom context (van Es & Sherin, 2002). Because of its ability to convey both realistic auditory and visual information, traditional video is the most common medium for studying noticing (Santagata et al., 2021). Yet recently, teachers' professional noticing has been examined with a new format of media that conveys more physiological information than traditional video. *Extended reality* (XR) is an umbrella term for media that blends the digital and physical worlds and has been used to examine noticing through virtual reality via 360 video (Buchbinder et al., 2021; Kosko et al., 2021) and digitized humans (Huang et al., 2021). The medium allows for novel ways for decomposing practice by not only articulating what might be attended to in a scene, but where one may look and/or listen within one's recorded environment (Weston & Amador, 2021). Rather, such media have higher degrees of *perceptual capacity*, or "a medium's capacity for aspects of the scenario to be perceivable" (Kosko et al., 2021, p. 286). This higher degree of perceptual capacity has allowed for study of how written descriptions and embodied attending (where one looks) are associated (Kosko et al., 2021; Walshe & Driver, 2019), as well as facilitating teachers' growth in noticing by discussing their physical actions associated with attending (Weston & Amador, 2021). In addition to XR-based media, scholars have also used other technology, such as eye-tracking (Huang et al., 2021) and field of view (Kosko et al., 2021) to examine physiological factors related to noticing.

This paper builds upon the emerging literature on embodied noticing by focusing on the use of holographic representations of practice (Kosko, 2022) and . Past scholarship on XR and noticing has focused predominately on 360 video, which allows for to look in any direction in an omnidirectionally recorded scenario; thus, breaking away from a fixed location such as those recorded by traditional video (Buchbinder et al., 2021; Walshe & Driver, 2019). By contrast,

holographic representations convey the depth and volume of recorded subjects (Kosko, 2022). Thus, a teacher viewing a holographic student can lean in to look at them writing on their desk and also move to different sides of that student. We conjecture that this added affordance better approximates the sense of being with an actual flesh-and-blood student and may allow for a better understanding of noticing as a construct. Although there is mounting evidence for noticing as an embodied act, there is a need to better understand embodied noticing at a fundamental level. Thus, the purpose of the present study is to examine how PSTs' physical act of looking interacts with their professional noticing. To do so, we examined data from PSTs' eye-tracking and written noticing when viewing both holographic and standard video of students solving fraction division tasks.

Background Literature & Theoretical Perspectives

Professional Noticing of Children's Mathematics

Professional teacher noticing involves selecting aspects from perceived experience to attend to and interpret those aspects for the purpose of shaping the contexts and interactions around them (van Es & Sherin, 2021). As people begin their teacher education and are asked to attend to children's mathematical thinking, they initially attend to generic aspects such as student participation or their teacher's classroom management. Teachers' interpretations of these events are similarly limited to either generic descriptions of students or a focus on students' answers to the math problem (Stockero et al., 2017; van Es et al., 2017). Over time, what teachers attend to and how they interpret become more specific and student-centered. van Es et al. (2017) suggest that teachers transition to focusing on students' procedural reasoning before learning to attend to and interpret their conceptual reasoning at hand. Jacobs et al. (2010) observed a similar trend. Examining how teachers attended to children solving 43×6, Jacobs et al. (2010) observed some teachers described how children wrote specific numerals and added them in a certain order whereas other teachers attended specifically to children's use of partial products (i.e., 40×6 and 3×6). This led to the claim that "the skill of attending to children's strategies" (p. 193) to be of primary importance in developing teachers' knowledge for teaching mathematics.

The notion of more effective professional noticing being student-centered has found support in research examining the embodied nature of noticing. For example, Kosko et al. (2022) recorded where PSTs looked when viewing a 360 video of a lesson on the Commutative Property of Multiplication. They found that when PSTs looked more directly at students, as opposed to students being located at the edge of PSTs' field of view, they were more likely to describe students' reasoning about the Commutative Property. PSTs who looked more directly at the teacher in the 360 video were more likely to describe aspects of classroom management such as use of groups to facilitate learning. Others have observed similar trends regarding where PSTs look in viewing a 360 video and the quality of their mathematical noticing (Buchbinder et al., 2021; Weston & Amador, 2021). In addition to XR-related scholarship, use of eye-tracking technology provides additional support for the embodied nature of noticing. Results from such work suggests that more experienced, knowledgeable teachers have shorter eye-gaze durations when looking at students in a classroom, but that they look at students more often than PSTs (Dessus et al., 2016; Cortina et al., 2015). Indeed, PSTs have less focused gaze behavior to the point that though they have longer durations of focus on students, the total amount of time looking at any one student is less than more experienced teachers (Stahnke & Blömeke, 2021). Rather, experienced teachers spend more time looking at students overall, as experienced

teachers attend to multiple students for short durations per gaze but for a larger number of gazes across a lesson.

Professional noticing is both a psychological and embodied act (Scheiner, 2021). To better understand how physiological factors correspond with teachers' attending and interpreting of children's mathematics, there is a need to use technology that corresponds with the use of such physiological resources. In the next section, we review aspects of immersive representations of practice and how they facilitate study of embodied noticing.

Immersive Representations of Practice

There are various "different ways that practice is represented in professional education" (Grossman et al., 2009, 2058), with traditional video being the most common in teacher education (Austin et al., in press; Christ et al., 2017). However, XR-based experiences like virtual reality and 360 video are becoming more prevalent (Austin et al., 2022; in press) and have been found to support PSTs' engagement and understanding of pedagogy (Buchbinder et al., 2021; Ferdig et al., 2020; Gandolfi et al., 2021; Walshe & Driver, 2019). XR-based representations are more immersive than traditional media because they have higher degrees of perceptual capacity and, thus, "convey [more] aspects perceivable through human experience" (Austin et al., in press, p. 2). Figure 1 juxtaposes a diagram of a user-teacher viewing a standard video on a screen versus a 360 video. For a standard video, teachers must view what is on the screen and provided to them by the videographer. For 360 video, teachers may choose to look elsewhere at a different group of students or at some other aspect in the classroom.

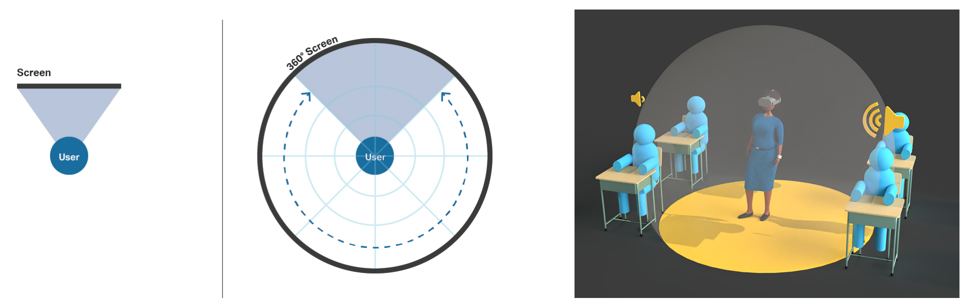

Figure 1: Traditional video versus 360 video with illustration of a teacher in VR.

XR facilitates embodied cognition, which is based on the "reactivation and reuse of processes and representations involved in perception and action" (Fincher-Kiefer, 2019, p. 10). For example, Buchbinder et al. (2021) had students record their own teaching with 360 video and then rewatch them. Rather, preservice teachers (PSTs) reflected while teaching as well as while viewing the 360 video of their own teaching. By being able to look at multiple students and themselves in the 360 video, PSTs were able to attend to "aspects of teaching pertaining to both their own teaching and to their student learning" (p. 301). The ability to look, spatially, in any direction allowed for a more nuanced connection to their lived experience of teaching the lesson than standard video would have alone (Walshe & Driver, 2019; Weston & Amador, 2021). Similar connections to embodied cognition have been made when PSTs view 360 video of others' teaching. For example, Kosko et al. (2022) observed that PSTs who looked more directly at students, and not the teacher, during the recorded class discussion were more likely to describe the mathematics concepts students were engaging. Rather, by centering students in their field of

view, PSTs were more likely to describe the mathematics they were learning at a conceptual level.

Although scholarship on 360 video is promising, XR is a broad field with an ongoing turnover of technology-mediated solutions. A recent innovation that requires attention is holograms. Holographic representations of practice record “3D images onto a space” (Yoo et al., 2022, p. 2) and convey “a sense of depth and volume such that the viewer can move around and closer/further from the recorded hologram” (Kosko, 2022, 1). There is preliminary evidence that viewing holograms of students can facilitate more detailed noticing than standard video alone (Kosko et al., 2022). One potential rationale for Kosko’s (2022) findings is that the volumetric aspects of the holographic recordings signal the human eye to focus on events perceived to be proximally closer. Gibson (1966) conjectured that the human eye is drawn to aspects proximally closer due partly to the distance that light travels between further and closer events. Figure 2 provides a rough illustration of how holographic representations of students may signal the eye to look more closely at the student’s desk, and, by consequence, they work they are doing with the mathematics at hand. The same recording in the format of traditional video would allow light to travel from the same distance anywhere on the screen, with only the perception of movement (not proximal distance) to signal attention to the teacher’s eyes. In the current paper, we used eye-tracking glasses to examine for this facet.

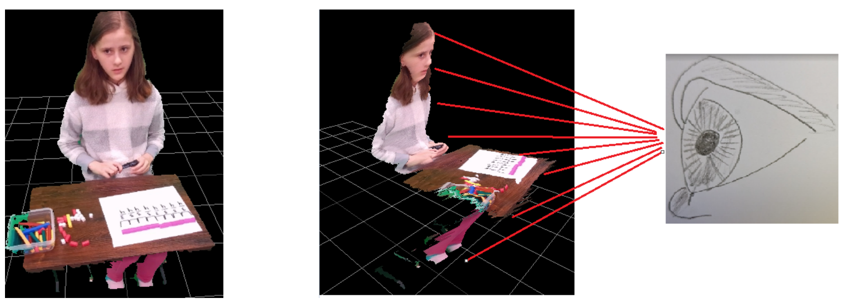

Figure 2: Perceptual distance of elements in a holographic student recorded.

More sophisticated teacher noticing involves attending to students’ mathematics at a more conceptual level (Jacobs et al., 2010; van Es et al., 2017). There is evidence that such noticing corresponds with physiological data associated with looking more specifically at students (Kosko et al., 2022). In this paper, we sought to further explore this relationship by using eye-tracking technology to study patterns in where PSTs focus when observing students’ mathematics, but also by incorporating holographic video to examine for the effect of spatial information. Thus, the purpose of the present study is to examine how PSTs’ physical act of looking interacts with their professional noticing. To do so, we examined data from PSTs’ eye-tracking when viewing both holographic and standard video of students solving fraction division tasks.

Method

Participants & Data

Participants included a convenience sample of 13 PSTs from a Midwestern U.S. university and majoring either in primary (n=11), middle grades mathematics (n=1) or secondary mathematics education (n=1). Data were collected in Fall 2022 from participants enrolled in a required educational technology course that preceded their mathematics methods coursework.

Participants predominantly identified as female (12 females; 1 male) and White (9 White; 3 Black; 1 as Asian, White, & Black)—the sole male participant identified as Black. As noted, participants were enrolled in an educational technology course. Students enrolled in this class receive course credit for participating in research studies, and each participant in this study received such credit.

Participants engaged in one-on-one sessions in which they wore eye-tracking glasses and viewed a set of recordings of two students. The eye-tracking glasses were Pupil Labs Core and include two 120Hz cameras recording pupil movement (one camera per eye) and one 30Hz camera recording in the direction the participant's head is pointed. Raw data from the glasses are transformed into viewable video with eye-gaze superimposed via the Pupil Labs software (Ehinger et al., 2019). PSTs' eye-tracking video while viewing recordings of students were a primary source of data.

Video viewed by participants included recordings of two students, Ben and Katherine, who solved tow fraction division problems using a length-based manipulative (Cuisenaire rods). The total video was 8 minutes 14 seconds long and included a scene of Ben working independently to solve the fraction division tasks of $6 \div \frac{3}{4}$ and $4 \div \frac{3}{4}$, followed by Katherine solving these independently, and then a scene with Ben and Katherine discussing how they solved $6 \div \frac{3}{4}$. For example, in solving $6 \div \frac{3}{4}$, Ben laid out 6 purple rods and 24 white cubes underneath (4 white cubes per 1 purple rod) before partitioning into four equal groups and counting all the 1s in the first three groups to find an answer of 18. Katherine also laid out 6 purple rods, but created groupings of 3 white cubes, identified each group as $\frac{3}{4}$, and counted the number of groups to find an answer of 8 (see Figure 3).

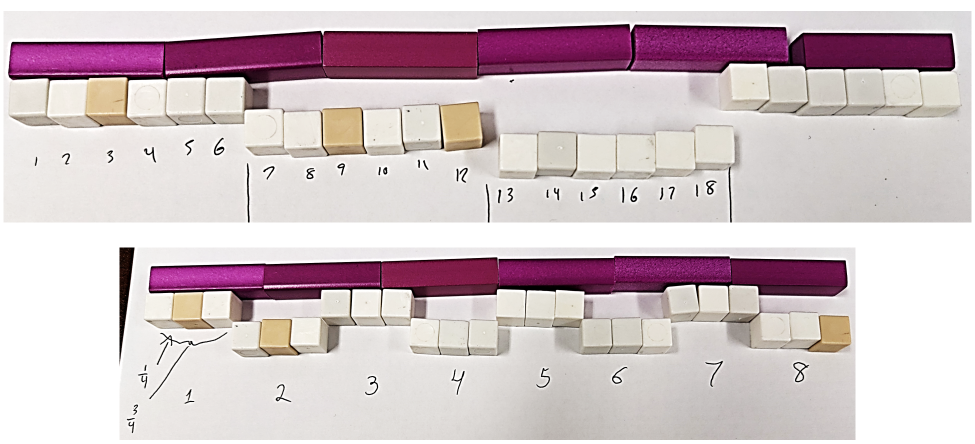

Figure 3: Illustration of Ben (top) & Katherine's (bottom) work for $6 \div \frac{3}{4}$.

The video included child actors playing the role of students using specific mathematical strategies. Both their actions and dialogue were scripted, which Herbst (2017) distinguishes as a useful feature in specific representations of practice. We used DepthKit software and Azure Kinect depth-sensing cameras to record a holographic video of the student actors. The recording can be viewed on a holographic display such as a LookingGlass Portrait (used in the present study) or as a standard video on a flatscreen device (i.e., tablet, computer screen). Figure 4 illustrates how viewing the holograms on the LookingGlass allowed for participants to move

their heads to the sides to see different angles of students, and that students' use of manipulatives appeared to be physically closer than students' faces/bodies (see also Figure 2). After viewing either a standard or holographic version of the video, participants then assessed each students' fraction reasoning and were solicited to provide at least two examples of evidence from the video to justify their assessment.

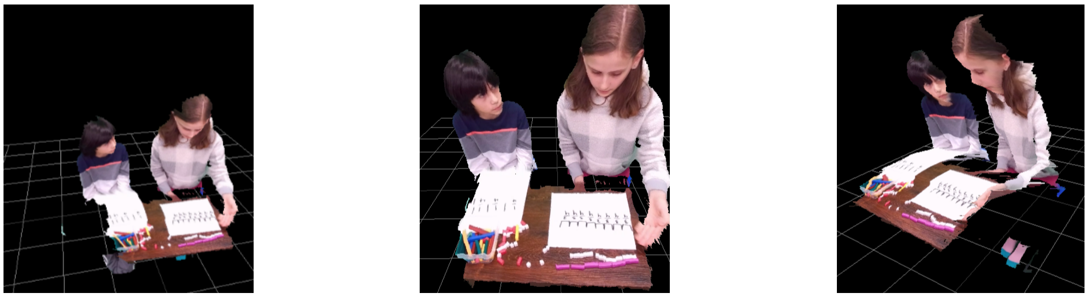

Figure 4: Scene from the holographic video from three different viewing perspectives.

Analysis & Results

Analysis in this paper focused on 13 PSTs' written noticing regarding what they attended to and interpreted of students' fraction thinking. For each participant, we also qualitatively examined videos of their eye-tracking data to examine for patterns in how and where PSTs looked when observing the recorded students. Finally, we examined for how themes from observed from written noticing and video viewing corresponded, and whether the medium of viewing affected this interaction (standard vs holographic video).

PSTs' written noticings. We used Systemic Functional Linguistics (SFL) to examine PSTs' written noticing. SFL analyzes of how grammar conveys meaning. In this study, we focused on the grammatical resource of reference chains. *Reference chains* are constructed grammatically through the repeated use of referents throughout a text. As a referent is included in text, the participant can connect it to prior references, and transform, expand, or clarify the conveyed meaning of what they reference (Eggins, 2004). In the present study, we focused on how participants referenced fractions and students' thinking. Following Kosko's (2022) approach to examining PSTs' written noticing, we used reference chains to examine the sophistication reasoning that mathematics teachers assessed and used these hierarchical themes as a priori categories in our own analysis.

Table 1 provides brief excerpts from five participants demonstrating one of four levels of sophistication. At the lowest level (Level 0), PSTs referenced a student's ability to find the answer and use procedures. For example, the participant in Table 1 references the number of "groups" in the fraction division problem, but only once and used it to support the reference chain for finding a correct answer via "solving the problem." At Level 1, PSTs' reference chains conveyed a focus on assessing children's ability to create and use fractional parts (i.e., partitioning). For example, the PST in Table 1 used the transitive processes (in bold) to "split" and "divide", but also "counted" the cubes in each group. At no point in this excerpt or the whole of this participant's writing did they reference coordination of parts to a whole but focused predominately on the child's partitioning and counting such partitions. At Level 2, PSTs referenced children's efforts to coordinate parts to the whole. The excerpt in Table 1 illustrates this with the participant's references to "groups of 3 to represent ¾" and noting that one white

block represented ¼ of a purple. Such referents are significant in that they explicitly convey particular entities as relationally bound to other objects. Level 3 noticings were characterized by references to children's coordination of non-unit fractions. In Table 1, the PST at Level 3 had referenced Katherine's grouping of three white blocks into groups labeled as ¾ each. In the excerpt below, the PST focused on how Katherine counted the ¾ groups within six wholes. Thus, this participant went beyond mere reference to part-whole coordination and referenced the student's operation with non-unit fractions. In this case, it was counting how many ¾ fit in 6.

Table 1: Excerpts of PSTs' Written Noticing by Classification

Level 0 *Ben = 46.2%* *Katherine = 30.8%*	[Katherine] *was able to* **solve** <u>the problem</u> correctly while **explaining** <u>the method she used to solve it</u>. She also **understood** <u>how many "groups"</u> **were needed** to **solve** <u>the problem</u>.
Level 1 *Ben = 38.5%* *Katherine = 30.8%*	Ben **counted** <u>each cube</u> and **split** <u>them</u> into <u>groups</u> correctly but **did not divide** by <u>the fraction</u>.
Level 2 *Ben = 0.0%* *Katherine = 15.4%*	[Katherine] **knew** // she *had to* **break** <u>the blocks up into groups of 3</u> to **represent** <u>¾</u> // since <u>one small block</u> **represented** <u>¼</u>.
Level 3 *Ben = 15.4%* *Katherine = 23.1%*	Katherine **separated** <u>the white blocks</u> into <u>multiple groups</u> <u>of ¾</u> and then **counted** <u>how many groups</u> she had to **get** <u>the answer</u>.

The first two authors qualitatively analyzed participants' written noticing independently before comparing findings. We used the weighted Kappa statistic and found sufficient agreement for participants' written noticing of Ben's ($\kappa = .434$) and Katherine's ($\kappa = .590$) mathematics. As indicated in Table 1, the distribution for which PSTs attended to fraction reasoning differed by the student they assessed. The bulk of participants focused on either students' answers or their partitioning for both Ben (84.6%) and Katherine (61.5%), with only two participants assessing both Ben and Katherine's coordination of non-unit fractions (Level 3).

Eye-tracking video. Next, we sought to understand where participants focused their attention. To do this, we used the Pupil Core eye-tracking glasses and recorded pupil fixation using two eye-directed cameras and one camera pointed to where the head was directed. Each participant's gaze was calibrated, with an accuracy within 0.6 degrees and we recorded video with eye-gaze dots for each participant's viewing of the standard and holographic recordings. Next, the first and third author qualitatively examined participants' eye-gaze patterns for emergent themes. Early in analysis, it was clear that PSTs viewing the holograms focused more prevalently on student work area (see Figure 5). This followed our initial conjecture that the area appearing physically closer would draw more attention by participants eye-gaze behavior. However, after an iterative process of examining for emergent themes, we noticed that some participants viewing both video and holograms followed students' hands more closely. It was whether and how participants' eye-gaze followed students' hands that mattered. Consider the

center and right-hand images in Figure 5 where one participant is looking at the desk area, but not specifically following the student's hand movements (middle). By contrast, the image on the right is from a participant whose gaze went between what the student wrote (labeling 3 white rods as ¾) and the rods the labels applied. Overall, 7 participants did not follow students' hands and 6 did. Interestingly, participants whose eye-gaze followed Ben and Katherine's hands while they solved the fraction division problems tended to be the same participants who referenced either part-whole reasoning or coordination of non-unit fractions.

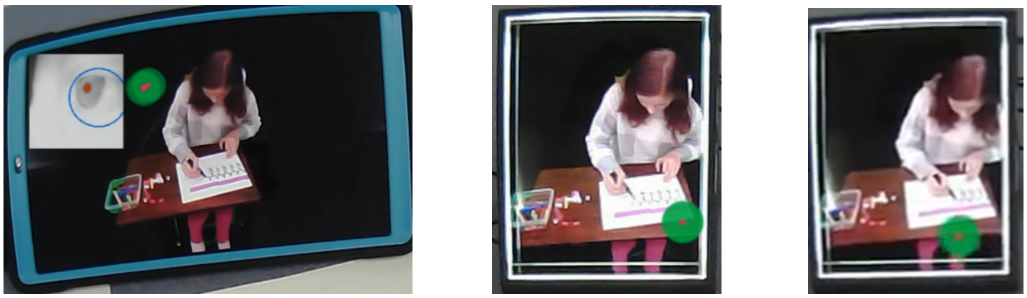

Figure 5: Two PSTs' eye-gaze not attending to student's hands while viewing standard video (left) and holographic video (middle), versus following student's hands (right).

Discussion

More sophisticated professional noticing involves attending to students' conceptual reasoning of mathematics, while less sophisticated noticing is either focused on procedures, answers, or generic aspects of classroom management (van Es & Sherin, 2021). The level of sophistication in teachers' noticing corresponds with physiological data with teachers focusing on more generic aspects of teaching looking at the classroom teacher instead of students (Kosko et al., 2022; Weston & Amador, 2021). Likewise, teachers who focus more on students tend to talk more in depth about the mathematics and students' conceptual understanding of it (Buchbinder et al., 2021; Kosko et al., 2022). Findings from the present study expand upon such scholarship by going beyond whether a teacher looks at a student and examining how they look at the student. Although many PSTs looked at Ben and Katherine's written work, only those PSTs who followed the students' hands as they coordinated the Cuisenaire rods referenced students' part-whole reasoning and coordination of the fractions.

Kosko (2022) observed that PSTs who watched holographic videos of Ben and Katherine were statistically more likely to describe their reasoning with more detail than those who watched these students with traditional video. Yet, findings here are less clear. PSTs' viewing holograms did focus more on students' desk area, but this did not necessarily translate to more sophisticated noticing either via writing or eye-tracking behavior. One potential reason for this is the sample in each study. Kosko (2022) studied PSTs late in their coursework with more experience in classroom field placements, and the sample here included PSTs with little field experience. Such a difference is worth further study. Sherin et al. (2008) argued that new technologies applied to the study and facilitation of professional noticing require study with larger samples and in varying contexts. Future work here will include a larger sample, with a focus on examining variation in its effect due to PSTs' prior field experiences.

Findings from this study are preliminary but provide additional empirical evidence for the embodied nature of professional noticing. Following Jacobs et al. (2010) and Kosko et al. (2022), findings here strongly support the notion of noticing as embodied and more effective noticing as

student-centered. One clear practical implication is for teacher educators to decompose practice in video (standard, holographic, or 360) by attending to how students are coordinating manipulatives with their hands and/or how and when they write about their mathematics. Regardless, this paper builds upon prior scholarship suggesting noticing is embodied (Kosko et al., 2021; Scheiner, 2021).

References

Austin, C. K., Kosko, K. W., & Hiesler, J. L. (in press). Mathematics and science teacher educators' use of representations of practice: A mixed methods study. School Science and Mathematics Journal. http://doi.org/10.1111/ssm.12563

Buchbinder, O., Brisard, S., Butler, R., & McCrone, S. (2021). Preservice secondary mathematics teachers' reflective noticing from 360-degree video recordings of their own teaching. Journal of Technology and Teacher Education, 29(3), 279–308. https://www.learntechlib.org/primary/p/219593/paper_219593.pdf

Christ, T., Arya, P., & Chiu, M. M. (2017). Video use in teacher education: an international survey of practices. Teaching and Teacher Education, 63, 22–35. https://doi.org/10.1016/j.tate.2016.12.005

Cortina, K. S., Miller, K. F., McKenzie, R., & Epstein, A. (2015). Where low and high inference data converge: Validation of CLASS assessment of mathematics instruction using mobile eye tracking with expert and novice teachers. International Journal of Science and Mathematics Education, 13(2), 389-403. https://doi.org/10.1007/s10763-014-9610-5

Dessus, P., Cosnefroy, O., & Luengo, V. (2016). Keep your eyes on 'em all!: A mobile eye-tracking analysis of teachers' sensitivity to students. In European Conference on Technology Enhanced Learning (pp. 72-84). New York: Springer. https://doi.org/10.1007/978-3-319-45153-4_6

Eggins, S. (2004). An introduction to systemic functional linguistics (2nd ed.). London: Continuum International Publishing Group.

Ehinger, B. V., Gross, K., Ibs, I., & Konig, P. (2019). A new comprehensive eye-tracking test battery concurrently evaluating the Pupil Labs glasses and the EyeLink 1000. PeerJ, 7, e7086. https://doi.org/10.7717/peerj.7086

Ferdig, R. E., & Kosko, K. W. (2020) Implementing 360 video to increase immersion, perceptual capacity, and teacher noticing. TechTrends, 64, 849-859. https://link.springer.com/content/pdf/10.1007/s11528-020-00522-3.pdf

Ferdig, R. E., Kosko, K. W., & Gandolfi, E. (2020). Effect and influence of ambisonic audio in viewing 360 video. Journal of Virtual Worlds Research, 13(2-3), 1-14. https://jvwr.net/wp-content/uploads/2020-Assembled-The-Use-of-Ambisonic-Audio-to-Improve-Presence.pdf

Fincher-Kiefer, R. (2019). How the body shapes knowledge: Empirical support for embodied cognition. Washington, D.C: American Psychological Association. https://doi. org/10.1037/0000136-000

Gandolfi, E., Austin, C., Heisler, J., & Zolfaghari, M. (2021). Immersive presence for future educators: Deconstructing the concept of presence in extended reality environments for preservice teachers. Journal of Technology and Teacher Education, 29(3), 339-367.

Gibson, J. J. (1966). The senses considered as perceptual systems. George Allen & Unwin LTD.

Grossman, P., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., & Williamson, P. W. (2009), Teaching practice: A cross-professional perspective. Teachers College Record, 111(9), 2055–2100. https://doi.org/10.1177%2F016146810911100905

Herbst, P. (2017). On dialogue and stories as representations of practice: An introduction. In R. Zazkis & P. Herbst (Eds.), Scripting approaches in mathematics education: Mathematical dialogues in research and practice (pp. 1-20). Springer. https://doi.org/10.1007/978-3-319-62692-5_1

Huang, Y., Richter, E., Kleickmann, T., Wiepke, A., & Richter, D. (2021b). Classroom complexity affects student teachers' behavior in a VR classroom. Computers & Education, 163. https://doi.org/10.1016/j.compedu.2020.104100

Jacobs, V. R., Lamb, L. L. C., & Philipp, R. A. (2010). Professional Noticing of Children's Mathematical Thinking, Journal for Research in Mathematics Education, 41 (2), 169-202. https://doi.org/10.5951/jresematheduc.41.2.0169

Kosko, K. W. (2022). Preservice teachers' professional noticing when viewing standard and holographic recordings of children's mathematics. International Electronic Journal of Mathematics Education, 17(4), em0706. https://doi.org/10.29333/iejme/12310

Kosko, K. W., Ferdig, R. E., & Zolfaghari, M. (2021). Preservice teachers' professional noticing when viewing standard and 360 video. Journal of Teacher Education, 72(3), 284-297. https://doi.org/10.1177/0022487120939544
Kosko, K. W., Heisler, J., & Gandolfi, E. (2022). Using 360-degree video to explore teachers' professional noticing. Computers and Education, 180, 1-13. https://doi.org/10.1016/j.compedu.2022.104443
Santagata, R., König, J., Scheiner, T., Nguyen, H., Adleff, A. K., Yang, X., & Kaiser, G. (2021). Mathematics teacher learning to notice: A systematic review of studies of video-based programs. ZDM–Mathematics Education, 53 119-134. https://doi.org/10.1007/s11858-020-01216-z
Scheiner, T. (2021). Towards a more comprehensive model of teacher noticing. ZDM–Mathematics Education, 53(1), 85-94. https://doi.org/10.1007/s11858-020-01202-5
Sherin, M. G., Russ, R. S., Sherin, B. L., & Colestock, A. (2008). Professional vision in action: An exploratory study. Issues in Teacher Education, 17(2), 27-46.
Stahnke, R., & Blömeke, S. (2021). Novice and expert teachers' noticing of classroom management in whole-group and partner work activities: Evidence from teachers' gaze and identification of events. Learning and Instruction, 74, 101464. https://doi.org/10.1016/j.learninstruc.2021.101464
Stockero, S. L. Rupnow, R. L., & Pascoe, A. E. (2017). Learning to notice important student mathematical thinking in complex classroom interactions. Teaching and Teacher Education, 63, 384-395. http://dx.doi.org/10.1016/j.tate.2017.01.006
van Es., E. A., Cashen, M., Barnhart, T., & Auger, A. (2017). Learning to notice mathematics instruction: Using video to develop preservice teachers' vision of ambitious pedagogy. Cognition and Instruction, 35(3), 165-187. https://doi.org/10.1080/07370008.2017.1317125
van Es, E., & Sherin, M. (2002). Learning to notice: Scaffolding new teachers' interpretations of classroom interactions. Journal of Information Technology for Teacher Education, 10(4), 571-596. https://www.learntechlib.org/p/9171/
van Es, E. A., & Sherin, M. G. (2021). Expanding on prior conceptualizations of teacher noticing. ZDM, 53, 17-27. https://doi.org/10.1007/s11858-020-01211-4
Walshe, N., & Driver, P. (2019). Developing reflective trainee teacher practice with 360-degree video. Teaching and Teacher Education, 78, 97-105. https://doi.org/10.1016/j.tate.2018.11.009
Weston, T. L., & Amador, J. M. (2021). Investigating student teachers' noticing using 360 video of their own teaching. Journal of Technology and Teacher Education, 29(3), 309–338. https://www.learntechlib.org/primary/p/219535/paper_219535.pdf
Yoo, H., Jang, J., Oh, H., & Park, I. (2022). The potentials and trends of holography in education: A scoping review. Computers & Education, 186, 1-16. https://doi.org/10.1016/j.compedu.2022.104533